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Measuring Low Rates of Erosion from Forest Fuel Reduction Operations

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Abstract. *A study was carried out to evaluate three methods for measuring low levels of hillside soil erosion associated with forest fuel management activities, and to measure erosion from cable logging and skid trails. The tipping bucket device with a sediment basin appears to be a better tool for this application than silt fences or rillmeter analysis.*

The greatest erosion following disturbance was measured with the tipping buckets on the cable trail and with silt fences on the high traffic skid trails. Further work is required to analyze the impacts of slope, cover, and compaction on these two treatments. Some of the control plots generated significant sediment from pocket gophers, which did not occur on any of the treated sites.

Keywords. Forest Engineering, Soil Erosion, Fuel Management

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Introduction

Because of fire suppression and logging practices during the last century, many forests in the United States have had a build up of small diameter trees that can exacerbate wild fires. To reduce this fuel buildup, forest managers are using numerous practices, including thinning, prescribed fire, and mulching. Thinning and prescribed fire may lead to increased soil erosion. Past research has shown that such erosion rates, however, can be small and difficult to measure (Covert et al., 2004). The purpose of this paper is to describe a study to evaluate three different methods for measuring low levels of soil erosion associated with thinning, and to report preliminary findings of those erosion rates.

Methods

An initial study was designed to evaluate monitoring methods as well as measure erosion from thinned sites.

Site Description

The site is located in the Clearwater National Forest, Palouse Ranger District, sections 5 and 8 of T41N, R2W and section 32, T42N, R2W approximately 5 miles northeast of Harvard, Idaho, (figure 1). Average elevation is about 1080 m. Precipitation for this area is about 560 mm per year, generally occurring in the fall, winter and spring months in the form of rain and snow. During the summer months limited amounts of precipitation are recorded. The precipitation events are usually low intensity. The soil texture is a sandy loam. The forest habitat type is grand fir/nine bark, common on south-facing slopes in this area.

The site was part of the Yellowpine timber sale that was harvested in the spring of 2002. The fuel management goal was to reduce 50 m² of basal area per hectare to approximately 20-25 m²/ha of basal area. Thinning in the spring of 2002 was followed by a prescribed burn in September, 2003. Three units were studied at the Yellowpine sale, units 1, 4 and 5. The harvesting method used for units 1 and 4 of the site were hand felled and cable logged, with 40 to 50 percent slopes. On the landing, the trees were de-limbed and stacked for hauling. Part of Unit 5 was cut using a feller buncher and a rubber-tired skidder transported logs to the landing as slopes were generally around 20 percent. Average slopes and aspects for the sites are given in Table 1.

Table 1. Erosion plot attributes

Plot	Date Installed	Date Sediment Measured	Number of plots	Average Aspect (Degrees)	Slope (Percent)
Unit 1 Cable trails with silt fences	June, '02	April, '03	9	176	38
Unit 1 Control silt fences	June, '02	Sept., '03	9	200	49
Unit 4 Cable trails with rillmeters and tipping buckets	Sept., '02 Nov., '02	June, '03	3	190	34
Unit 5 Skid trail silt fences	Sept., '02	June, '03	9	219	14

Figure 1. Yellow Pine Site

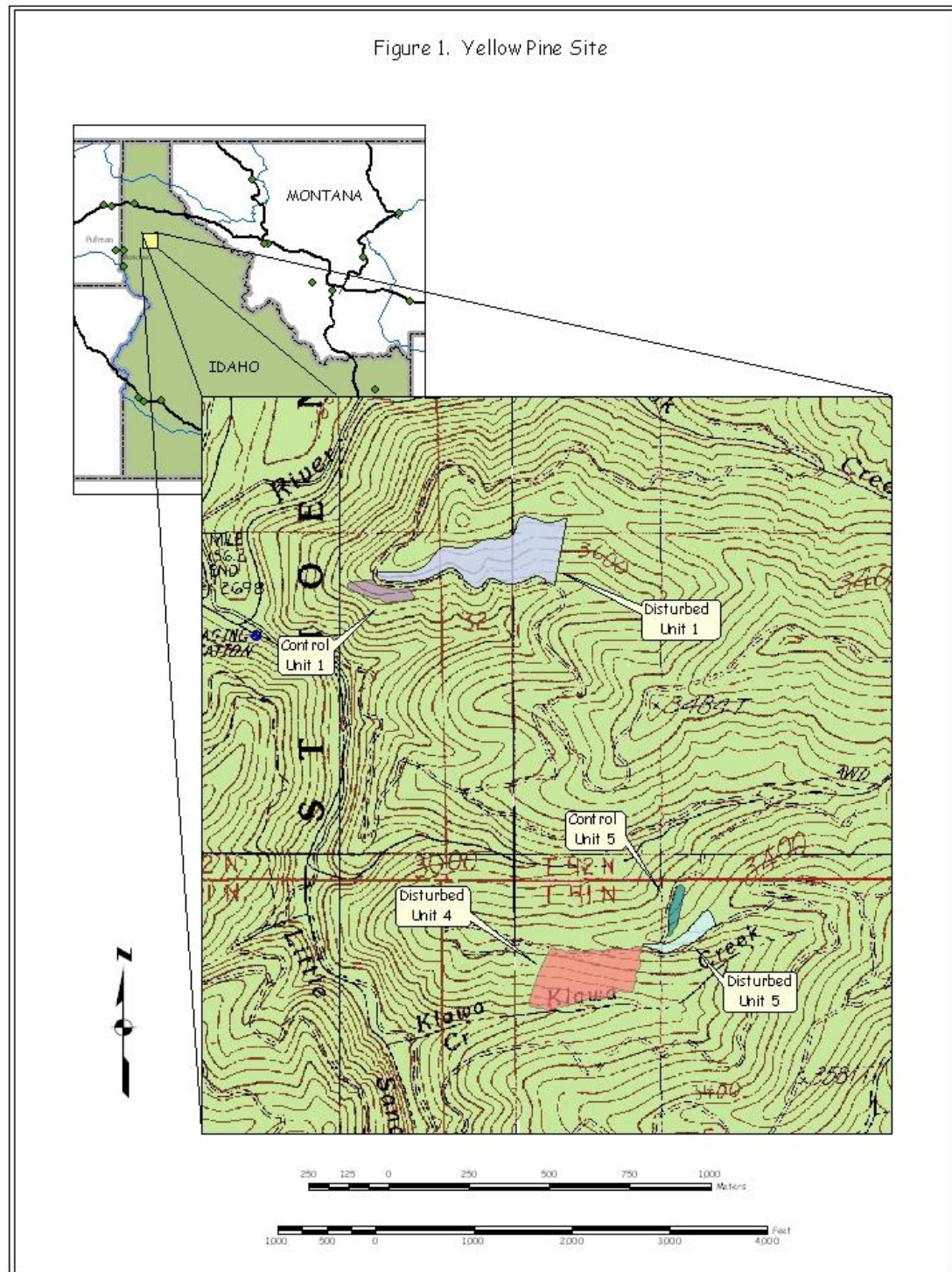


Figure 1. Location of research site.

Field Observations

Ground cover was estimated for each of the sites using a 1- square meter frame with wires every 10 cm. The type of cover at each wire intersection was noted. Ground cover was only done in the first year for the control, as there was no disturbance to change it.

Three methods were selected to measure low level rates of soil erosion in disturbed forests: silt fences (Robichaud, 2002), rill meter plots (Elliot et al. 1997) and runoff plots with tipping buckets and sediment traps (Kahn and Ong, 1997).

Silt Fences

Silt fences were installed on Units 1 and 5 in June of 2002. As recommended by Robichaud and Brown (2002), there were nine silt fence plots installed on the Unit 1 disturbed site and another nine on a nearby control site (Figure 1). The organic material was collected separately from any accumulated sediment in June or September, 2003 (Table 1). When the data were collected, we observed that on three of the fences, there had been considerable pocket gopher activity, and none on the other six. These three were kept separate in the data analysis. On the disturbed sites, the fences were spaced about 10 m apart along three of the disturbed cable logging trails. On the undisturbed sites, the plots were about 100 m², surrounded by sheet metal. The fences were removed in mid summer, 2003, before the prescribed burn. The prescribed was carried out in the fall of 2003, and the fences replaced in December.

On the area of Unit 5 disturbed by skidding, five silt fences were set up on the main skid trail, and four others on minor skid trails branching out from the main trail. On Unit 5, slash was piled in the spring of 2003, and the piles burned in the fall. The silt fences were not damaged from these activities.

The sediment and organic material amounts collected by the silt fence plots were analyzed with a general linear model, and a Duncan's multiple range analysis carried out on the dependent variables that were significantly different.

Rillmeter plots

Unit 4 was set up to serve as a rillmeter site. Reinforcing bars were driven about 90 cm into the ground along the side of the cable trail approximately every 20 cm, and an initial reading was taken. The bars will serve as reference elevations for all future readings. The rillmeter was modified so that one leg rested on the rod, and the other leg was lengthened until the rillmeter was level over the plot. A digital photograph was then taken of the pin readings for future analysis. Further readings were intended to be made each year until the site recovered.

Even though part of Unit 5 was not as steep as the other units (Table 1), the skidder operation provided an opportunity to compare another treatment, so nine additional silt fences were installed on the skid trails in unit 5.

Tipping bucket plots

Tipping bucket runoff measuring devices were fabricated in our machine shop, and designed to contain approximately 1 liter per tip. The tipping buckets were then individually calibrated for a range of flows (Moore et al., 1983; Kahn and Ong, 1997). At the bottom of three cable trails, tipping bucket collectors were installed. Sheet metal borders diverted runoff from the cable trail to a 56-liter sedimentation trap to collect the bedload. Overflow from the sediment trap was directed to the tipping bucket. A magnetic reed switch on the buckets recorded each tip, and an event logger stored the time of each tip. After completing the installation, the sediment traps were filled with clean water. Grab samples were taken during periods of runoff to estimate the

suspended sediment in the cable trail runoff. The data were analyzed with a program developed for processing data from a tipping bucket rain gage.

Soil Properties

Soil bulk density was evaluated for each treatment, and adjacent to each treatment, from undisturbed soil cores. Soil particle size distribution of the soil cores was determined by dry sieving and pipetting.

Climate

The daily precipitation and average temperature were recorded from October 30, 2002, until May 10, 2004. The distribution of precipitation and the average daily temperature are shown in 36a. Total precipitation during the first year of the study (October 30, 2003 to October 29, 2004) period was 742 mm.

Ground Cover

The observed ground cover is presented in Table 2. The reduction in cover from 2002 to 2003 for unit 1 is due to the broadcast prescribed fire on that unit. The majority of the ground cover was decomposing litter, with a few branches and some ash following the prescribed fire.

Table 2. Observed percent ground cover.

	Unit and Treatment		
	1 – Cable logging with silt fences	4 – Cable logging with tipping buckets	5 – Skidder with silt fences
Control Summer, 2002	98	-	97
Disturbed Summer, 2002	94	90	70
Disturbed Spring 2003	86	93	87

Bulk Density

Bulk density values are presented for the two units that were cable logged in table 3.

Table 3. Bulk density observations (g/cm³)

Location	0 – 10 cm	10 – 20 cm
Cable Control	1.10	1.33
Cable logging off trail	1.14	1.46
Cable logging on trail	1.23	1.44
Skidder off trail	0.91	1.01
Skidder on trail	1.03	1.12

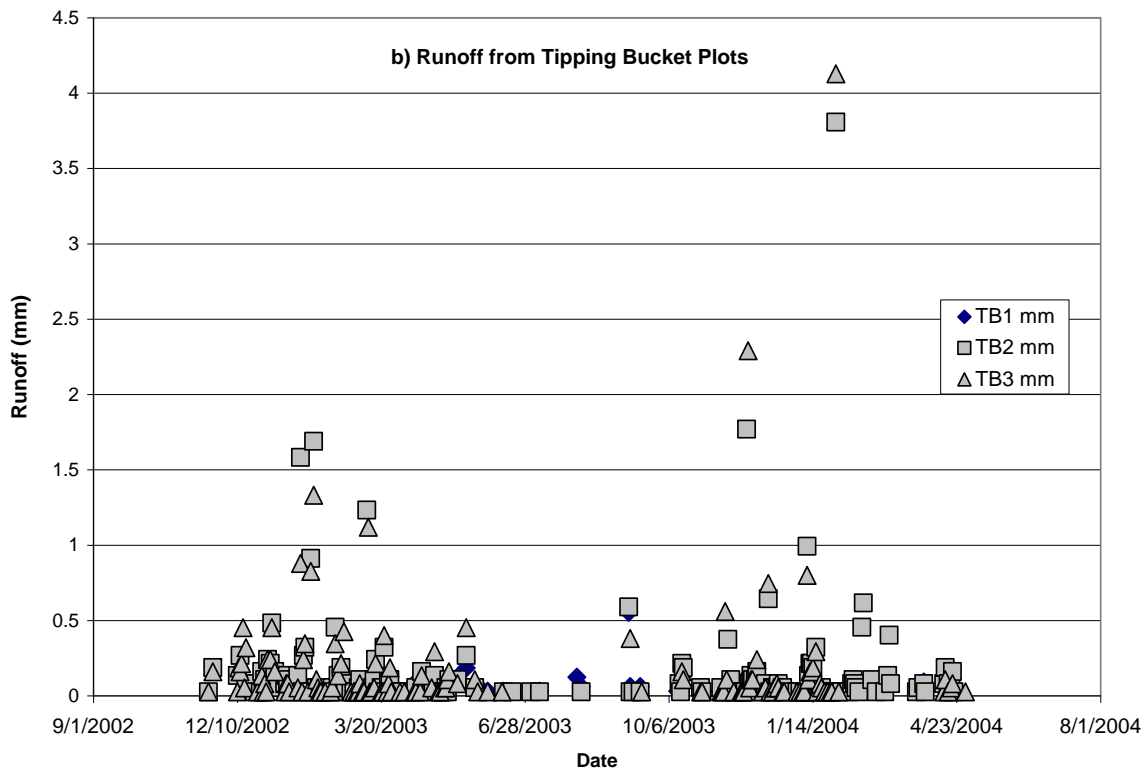
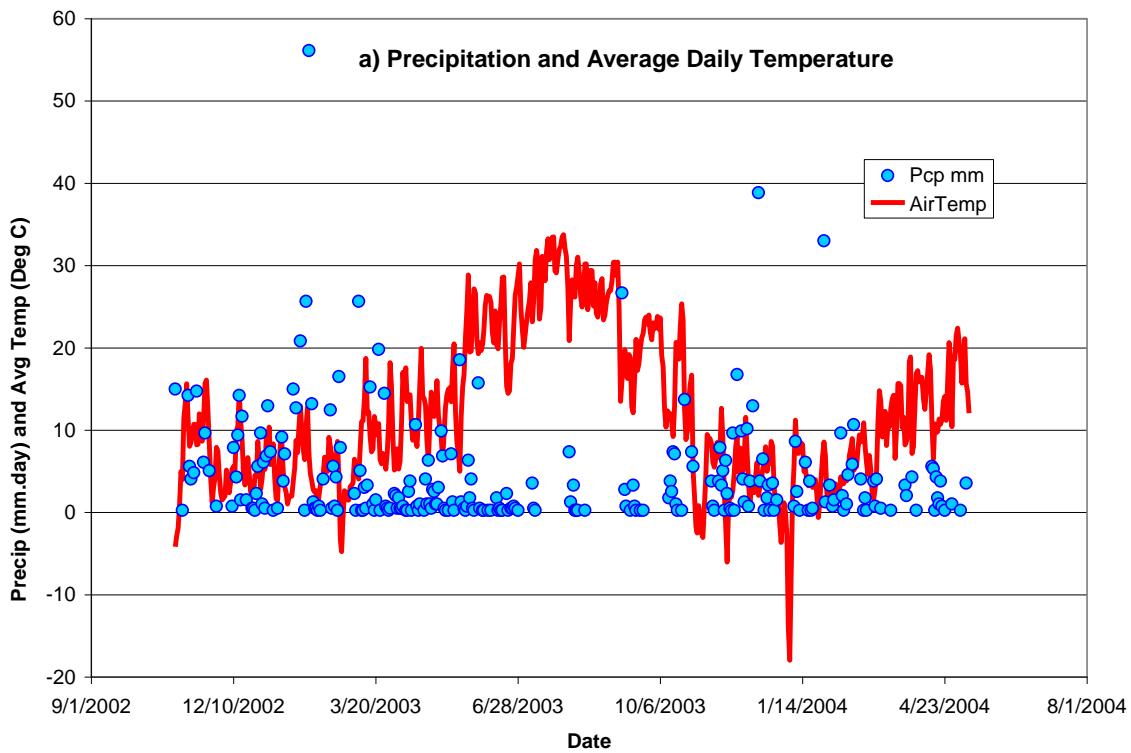


Figure 2. a) Distribution of Precipitation and average daily temperatures during the study; b) Runoff recorded from tipping bucket plots.

Soil Loss

The amount of organic material collected behind the silt fences ranged from 0.35 to 84.77 kg/ha, with a mean of 21.80 and a standard deviation of 19.68 kg/ha. There were no significant differences between treatments.

Soil loss values are presented in table 4. Only values from the silt fence plots and the tipping bucket plots are presented. Rillmeter analysis is ongoing. About 40 percent of the tipping bucket sediment came from the trap, and 60 percent settled in front of the sheet metal plot borders diverting runoff to the sediment basin. Less than 0.05 percent of the tipping bucket eroded sediment was observed in the suspended sediment.

A general linear model analysis was carried out on all of the silt fence plots. The results showed that there was a difference between treatments in the amount of sediment collected. A Duncan's Multiple Range analysis was used to determine which treatments were different and the differences are noted in Table 4.

Runoff

Runoff was only measured on the three tipping bucket plots on the cable trails. Figure 2b presents the runoff depth from each of the three plots. Total runoff amounts during the data collection period from Plots 1, 2, and 3, were 2.43, 13.94, and 13.30 mm respectively. The runoff from the cable trail plots 2 and 3 averaged about 13.6 mm from 742 mm of precipitation, or about 1.8 percent of the precipitation. The greatest daily amount of runoff was associated with a large storm on February 1, 2003 (56.13 mm precipitation and 1.5 mm runoff) (Figure 2). A second storm after the study was complete was on January 29, 2004, when 33.02 mm of precipitation resulted in 4 mm of runoff.

Discussion

Measurement Methods

The silt fences were relatively inexpensive to install and maintain. They do not, however provide any runoff data. This is not a concern if monitoring for upland soil displacement, but it does make this method less suitable for developing or validating models.

The silt fences collected significantly less sediment than the tipping buckets (Table 4). This may be because the openings in the woven silt fence were 0.42 mm, whereas over 80 percent of the sediment collected by the tipping bucket plots was under 0.074 mm diameter. Robichaud and Brown (2002) reported that on agricultural sites, silt fences were over 90 percent efficient. At the low erosion rates on these forest sites, however, the fences may be less efficient. Britton et al. (2000) stated that the relatively large openings in silt fence fabric were blocked with sediment smaller than those openings as sediment laden water passed through the fabric. It is not clear if there was enough sediment in the runoff from these studies to sufficiently block the fabric so that the fine sediments would be retained.

Installation of the rillmeter stakes, taking the readings, and later analyzing the pins proved to be extremely time consuming. In addition, when we returned to the plots in the spring of 2004, we found that there was an accumulation of dead trees and branches at some of the cross sections, making it impossible to take readings without disturbing the plot. Because of these reasons, we decided to stop the study, and let the tipping buckets at the bottom end of these plots provide the desired erosion information.

The tipping bucket appears to show the greatest promise for measuring the low levels of erosion associated with fuel reduction practices. It provides both runoff information as well as sediment

Table 4. Soil loss results

Plot	Number	Mean (kg/ha)	Standard Deviation (kg/ha)
Cable logging control silt fences, no animals	6	0.64 A*	0.45
Cable logging control silt fences, with animal activity	3	220.38 B	92.10
Cable logging followed by fire, silt fences	9	1.04 A	1.44
Skidder with silt fences, main trail	5	127.56 B	187.41
Skidder with silt fences, side trail	4	0.75 A	1.07
Cable logging tipping buckets	3	197.67	60.89

* Results with the same letters are not significantly different ($\alpha = 0.05$)

data. The amount of sediment associated with the tipping buckets was greater than from silt fences on the similar plots (Table 4). This difference may be due to the inability of the silt fences to collect all of the sediment under the extremely rough surface conditions. Another concern is that even though the tipping bucket on plot 1 recorded only a tenth the runoff of the other two plots, the amount of sediment was about the same (for plots 1, 2, and 3, the observed erosion rates were 267, 367, and 313 kg/ha respectively). This suggests that the bucket may have not been functioning correctly. Future studies using this method may require regular monitoring to ensure the equipment is working.

Field Data Observations

From table 2 it is apparent that the feller/buncher plus skidding harvesting system exposes more soil than does the hand felling and cable system. It is also apparent that on this site, the prescribed fire maintained a cover within the established Forest Service regional guidelines (Dumroese et al., 2000).

There did not appear to be any increase in bulk density with depth from the cable treatment (Table 3), but there was with the skidder treatment. This is similar to a geotechnical principle, that heavier loads, even if spread across the soil, cause stresses deeper in the soil than lighter loads. There was some increase in bulk density in the 1 – 10 cm depth on the cable trail.

There are some unexpected results in table 4. The relatively high soil loss on the control sites was not expected. This loss was due mainly to pocket gophers that were extremely active on the undisturbed control, but were not present on the treated sites. Soil displacement by gophers is unlikely to adversely impact onsite productivity or offsite sedimentation. It is also clear that the main skid trail where there were multiple passes experienced considerably more erosion than the feeder trails with fewer passes. Table 4 does open up some questions about whether there is more erosion on skid trails than on cable trails, with differences on the skid trails due to amount of traffic, and likely differences in erosion on the cable corridors due to measurement

method. Erosion is impacted by cover, steepness, and soil compaction, and further work is required to fully quantify these differences.

The tipping buckets measured greater erosion on the cable corridors than the silt fences. This may be because of the difficulty observed in ensuring that all runoff passed through the silt fence, or that the silt fence was not efficient at collecting low such relatively low levels of erosion. The cable trails were uneven, with numerous branches and roots mixed in with the soil, making it difficult to install the fences.

Conclusions

The objectives of this study were to evaluate methods for measuring low levels of erosion associated with fuel management activities, and to measure those levels. From this study, it appears that the best method for evaluating erosion rates at the hillslope scale is the tipping bucket. It is not clear whether a cable system or a rubber skidding system generate more erosion, and further work is required to address this question.

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